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WASTES IN PRODUCTION

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THERMOMECHANICAL STUDIES OF CERAMIC TILE MADE FROM TECHNOGENIC RAW MATERIALS

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The studies described make it possible to judge the strain – stress state of ceramic articles at different stages of firing and to establish their effect on the thermomechanical properties of the material. The studies showed that the introduction of pyrite cinders into ceramic paste lowers the elastic modulus by 25 – 30% during the initial period (to 400°C) and 4 – 10% in the temperature interval 500 – 1000°C. These data show that pyrite cinders can be used to intensify firing.

Key words: ceramic tile, thermomechanical studies, pyrite cinders, clayey part of the gravity “tailings,” firing temperature, elastic modulus, thermal expansion, optimal firing regime.

It has been shown that pyrite cinders and the clayey part of the gravity “tailings” of zircon-ilmenite ores can be used, in principle, in the production ceramic tiles without using the conventional natural raw material [1 – 4]. The porosity structure and phase transformations during firing of the tile made from technogenic raw materials are investigated in [5, 6].

The study of the processes involved in the firing of ceramic materials and development for their production of the optimal regime are largely associated with thermomechanical studies. The article presents the thermomechanical studies of tile made from technogenic raw material without using the conventional natural materials.

It is well known that ceramic articles are subjected during service to thermal stresses which depend on the temperature difference between the surface and the center of an article. The magnitude of these stresses can exceed the mechanical strength of the articles, which will cause the articles to fracture.

To study the thermomechanical properties of tile two compositions (wt.%) were studied: 1) CZI (clayey part of the gravity “tailings” of zircon-ilmenite ores) — 100; 2) CZI — 80, pyrite cinders — 20.

The thermomechanical properties of tiles were studied by the method of [7 – 8] on a facility consisting of a heating chamber into which the sample pressed by pistons made of heat-temperature steel was inserted. Refractory brick in the heating chamber prevents heat outflow. Asbestos fabric, which transfers forces evenly on the surface of the refractory brick, protecting it from destruction, performs a similar function. The indicators for determining the deformation of the tested sample are mounted on a massive metal support. To eliminate any effect of deformation of the piston, slab, insulation, and body on the results of the measurements, the deformation of the sample was calculated taking account of the difference of the positions of the left- and right-hand indicators. To this end the indicators were bound with the surface of the piston by tubes. Thus, on the one hand they touched the surface of the piston and on the other hand they fell short of the surface of the bottom piston by a distance 2 – 3 mm. The pressure was recorded with a manometer. The deformation of the samples was measured with a watch type indicator with scale division 0.001. The temperature in the chamber was regulated automatically [7].

The tests were conducted on samples consisting of prisms of height $h = 5 \times 10^{-2}$ m with equilateral surfaces of different size: $a = b = 2, 3, 4, 5$ cm. The samples were tested for strength after isothermal soaking for 1 h at appropriate temperatures (Fig. 1).

Analysis of the results of the thermomechanical tests show that the strength of the ceramic samples fired at 1050°C with increasing rate of heating and thickness of the samples decreases appreciably (see Fig. 1). This is explained

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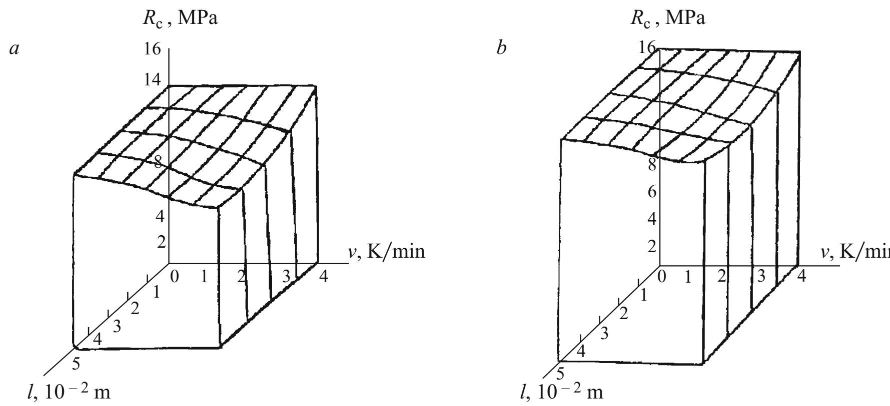

Fig. 1. Strength of samples fired at 1050°C with different rate of heating: *a*) composition 1; *b*) composition 2.

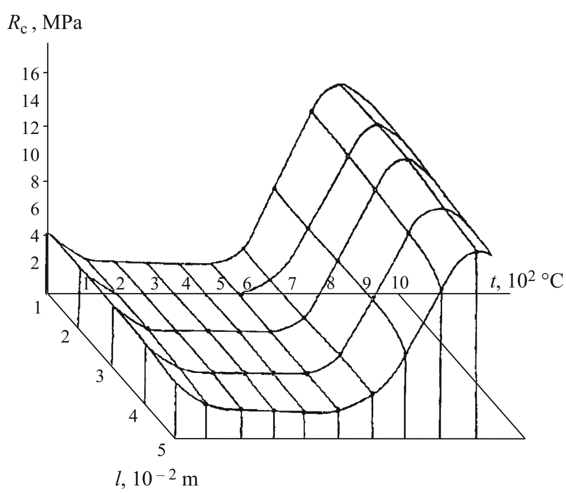

Fig. 2. Strength of ceramic sample with composition 2, fired with isothermal soaking for 1 h at temperatures from 100 to 1000°C.

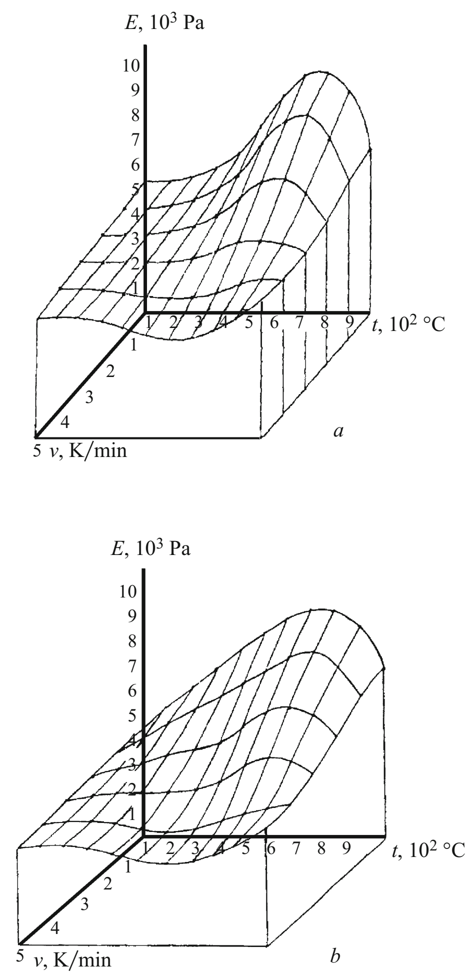

Fig. 3. Elastic modulus of a ceramic sample versus the temperature and heating rate: *a*) composition 2; *b*) composition 1.

by the increase of the temperature differential and therefore the thermal stresses in the samples.

A feature of the behavior of the ceramic samples in an alternating temperature field is that thermal stresses and strains appear under conditions where the physical–chemical properties of the samples can change appreciably. The difference of the rates of the physical–chemical processes in nonuniformly heat zones of the sample also gives rise to additional stresses and strains.

Figure 2 shows the strength indicators of samples with composition 2 and different size, emplaced after isothermal soaking for 1 h at temperatures from 100 to 1000°C (100°C intervals). Temperature equalization in the samples reaches 90 – 95%, as a result of which the temperature differential in the articles is negligible. Therefore nonuniformity of expansion and shrinkage over the volume of the sample at this temperature is practically excluded.

It is known that the magnitude of the temperature stresses arising is proportional to the CLTE, the elastic modulus, and the temperature gradient [7 – 8]. Thus, to evaluate the internal stresses in it is necessary to have information about, in addition to the CLTE and the temperature gradient, the change of the elastic modulus of the materials versus the rate of heating and their firing temperature. Figure 3*a* displays the elastic modulus of the sample with composition 2 versus the temperature and the rate of heating. For comparison, a similar characteristic for CZI samples with composition 1 without pyrite cinders is displayed in Fig. 3*b*.

The elastic modulus of the sample with composition 2 remains practically unchanged to 400°C. A significant change of the elastic modulus is observed at temperatures above 400°C, reaching a maximum at 800°C. As the heating rate increases (to 4 – 5 K/min) the elastic modulus decreases as a result of a disruption of the continuity of the material. In the interval 800 – 1000°C the elastic modulus decreases appreciably, which is explained by the appearance of a liquid phase.

For a sample with composition 1 the elastic modulus increases systematically from the start of heating to 800°C, and subsequently a similar picture is observed. Comparing these data for the samples with compositions 2 and 1 shows that the elastic modulus of sample 1 is lower by 25 – 30% than for sample 2 in the initial period (to 400°C) and by 5 – 10% in the temperature interval 500 – 1000°C. These data show that firing can be intensified by using pyrite cinders.

CONCLUSIONS

The data obtained make it possible to judge the stress–strain state of ceramic articles at different stages of firing and to determine their effect on the thermomechanical properties of the material. The investigations have shown that introducing pyrite cinders into ceramic pastes lowers the elastic modulus by 25 – 30% in the initial period (to 400°C) and 5 – 10% in the temperature interval 500 – 1000°C. Therefore firing can be intensified by adding pyrite cinders.

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